

WHAT IS CLAIMED IS

5

1. A semiconductor light emitter,
comprising:

a quantum well active layer which includes
nitrogen and at least one other Group-V element; and
10 barrier layers which are provided
alongside said quantum well active layer, wherein
said quantum well active layer and said barrier
layers together constitute an active layer,

wherein said barrier layers are formed of
15 a Group-III-V mixed-crystal semiconductor that
includes nitrogen and at least one other Group-V
element, a nitrogen composition thereof being
smaller than that of said quantum well active layer.

20

2. The semiconductor light emitter as
claimed in claim 1, wherein said barrier layers
25 further include phosphorus.

5 3. The semiconductor light emitter as
claimed in claim 1, wherein said barrier layers are
one of GaNAs, GaNPAs, GaInNAs, GaInNPAs, GaNAsSb,
GaNPAsSb, GaInNAsSb, and GaInNPAsSb.

10

 4. A semiconductor light emitter,
comprising:
15 a quantum well active layer which includes
nitrogen and at least one other Group-V element;
 barrier layers which are provided
alongside said quantum well active layer, wherein
said quantum well active layer and said barrier
20 layers together constitute one active layer;
 upper and lower reflectors which are
respectively provided on upper and lower sides of
said one active layer, wherein said one active layer
and said upper and lower reflectors together
25 constitute a resonator structure;

a GaAs substrate on which said resonator structure is formed; and

spacer layers which are provided between said upper and lower reflectors and said one active
5 layer,

wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes nitrogen and at least one other Group-V element, and said spacer layers are mainly formed of
10 a material having a larger band gap than GaAs.

15 5. The semiconductor light emitter as claimed in claim 4, wherein said material having a larger band gap than GaAs is one of GaInPAs and AlGaAs.

20

6. The semiconductor light emitter as claimed in claim 1, wherein said semiconductor light
25 emitter is a surface emitting semiconductor laser.

5 7. The semiconductor light emitter as
claimed in claim 4, wherein said semiconductor light
emitter is a surface emitting semiconductor laser.

10

8. An optical transmission module,
comprising the semiconductor light emitter of claim
6 serving as a light source.

15

9. An optical transmission module,
20 comprising the semiconductor light emitter of claim
7 serving as a light source.

25

10. An optical transceiver module,
comprising the semiconductor light emitter of claim
6 serving as a light source.

5

11. An optical transceiver module,
comprising the semiconductor light emitter of claim
10 7 serving as a light source.

15 12. An optical communication system,
comprising the semiconductor light emitter of claim
6 serving as a light source.

20

13. An optical communication system,
comprising the semiconductor light emitter of claim
7 serving as a light source.

25

14. A method of making a semiconductor
5 light emitter, said semiconductor light emitter
including a quantum well active layer which includes
nitrogen and at least one other Group-V element, and
barrier layers which are provided alongside said
quantum well active layer, wherein said quantum well
10 active layer and said barrier layers together
constitute an active layer, wherein said barrier
layers are formed of a Group-III-V mixed-crystal
semiconductor that includes nitrogen and at least
one other Group-V element, a nitrogen composition
15 thereof being smaller than that of said quantum well
active layer, said method comprising the steps of:

providing a plurality of Ga raw material
cells in a molecular beam epitaxy apparatus; and

growing the quantum well active layer and
20 the barrier layers by use of the respective Ga raw
material cells, an amount of Ga supply of the cell
used for growing the quantum well active layer being
smaller than an amount of Ga supply of the cell used
for growing the barrier layers.

15. A semiconductor light emitter,
5 comprising:

a GaAs substrate; and

an active region which is grown on said
GaAs substrate, wherein said active region
comprises:

10 a quantum well active layer which is made
of a mixed-crystal semiconductor having a
compressive strain and containing nitrogen and at
least one other Group-V element; and

a strain-compensated layer which is
15 situated alongside said quantum well active layer,
and has a multi-layer structure that includes a
first layer containing nitrogen and having a lower
conduction band than GaAs and a second layer with a
tensile strain including phosphorous and having a
20 higher conduction band than GaAs, said first layer
being situated closer to said quantum well active
layer than said second layer.

16. The semiconductor light emitter as claimed in claim 15, wherein said quantum well active layer is a multiple quantum well active layer.

5

17. The semiconductor light emitter as claimed in claim 15, wherein said first layer has a tensile strain relative to GaAs.

15

18. The semiconductor light emitter as claimed in claim 15, wherein said quantum well active layer is a multiple quantum well active layer including a plurality of quantum well active layers and barrier layers between said quantum well active layers, said barrier layers including either phosphorous or nitrogen and having a tensile strain

25

19. The semiconductor light emitter as
claimed in claim 18, wherein the tensile strain of
said second layer is larger than the tensile strain
5 of said barrier layers.

10 20. The semiconductor light emitter as
claimed in claim 15, wherein said multi-layer
structure further includes an incremental-
composition layer in which a strain continuously
changes.

15

21. The semiconductor light emitter as
20 claimed in claim 15, wherein said second layer is a
GaAsP layer, and said first layer is a GaAsN layer,
a GaAsP composition of said GaAsP layer being $\text{GaAs}_{(1-x)}\text{P}_x$ ($0 < x \leq 0.2$), and the GaAsN layer situated next
said quantum well active layer having a thickness of
25 1 nm or more.

5 22. The semiconductor light emitter as
claimed in claim 15, wherein said semiconductor
light emitter is a surface emitting semiconductor
laser.

10

 23. An optical transmission module,
comprising the semiconductor light emitter of claim
15 15 serving as a light source.

20 24. An optical communication system,
comprising the optical transmission module of claim
23 serving as an optical transmission module.

25

25. A quantum well structure, comprising:

a quantum well layer which includes In and nitrogen and at least one other Group-V element and

5 has a compressive strain; and

barrier layers which are provided on upper and lower sides of said quantum well layer, wherein each of said barrier layers includes a layer including In and phosphorous and situated alongside
10 said quantum well layer and a layer having a tensile strain.

15

26. A semiconductor light emitter, comprising:

a quantum well layer which includes In and nitrogen and at least one other Group-V element and

20 has a compressive strain; and

barrier layers which are provided on upper and lower sides of said quantum well layer, wherein said quantum well layer and said barrier layers together constitute a quantum well structure serving
25 as an active layer, and each of said barrier layers

includes a layer including In and phosphorous and situated alongside said quantum well layer and a layer having a tensile strain.

5

27. The semiconductor light emitter as claimed in claim 26, wherein the layer including In and phosphorous and situated alongside said quantum well layer has band gap energy that is lower than or equal to that of GaAs.

15

28. The semiconductor light emitter as claimed in claim 26, wherein the layer including In and phosphorous and situated alongside said quantum well layer has a strain of $\pm 0.1\%$ or less.

25

29. The semiconductor light emitter as

claimed in claim 26, wherein each of said barrier layers includes an incremental composition layer.

5

30. The semiconductor light emitter as claimed in claim 26, wherein the active layer has a multiple quantum well structure.

10

31. The semiconductor light emitter as claimed in claim 26, wherein said semiconductor light emitter is a surface emitting semiconductor laser.

20

32. The semiconductor light emitter as claimed in claim 26, wherein the layer including In and phosphorous and situated alongside said quantum well layer is made of GaInAsP.

25

5 33. An optical transmission module,
 comprising the semiconductor light emitter of claim
 26.

10

 34. An optical transmission system,
 comprising the optical transmission module of claim
 33.

15

 35. A semiconductor light emitter,
20 comprising:

 a GaAs substrate;

 a quantum well active layer which includes
 nitrogen and at least one other Group-V element, and
 has a compressive strain relative to said GaAs
25 substrate; and

barrier layers which are provided alongside said quantum well active layer, wherein said quantum well active layer and said barrier layers together constitute an active layer,

5 wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes antimony, and said quantum well active layer does not include antimony.

10

36. The semiconductor light emitter as claimed in claim 35, wherein said barrier layers
15 further include nitrogen.

20 37. A semiconductor light emitter, comprising:

 a GaAs substrate;

 a quantum well active layer which includes nitrogen and at least one other Group-V element, and
25 has a compressive strain relative to said GaAs

substrate; and

barrier layers which are provided
alongside said quantum well active layer, wherein
said quantum well active layer and said barrier
5 layers together constitute an active layer,

wherein said barrier layers are formed of
a Group-III-V mixed-crystal semiconductor that
includes antimony and nitrogen, and said quantum
well active layer has no or some concentration of
10 antimony smaller than an antimony concentration of
said barrier layers and has an nitrogen
concentration larger than that of said barrier
layers.

15

38. The semiconductor light emitter as
claimed in claim 35, wherein said barrier layers are
20 formed of GaAsSb, GaNAsSb, GaInNAsSb, GaNPAsSb,
GaPAsSb, GaInNPAsSb, GaInPAsSb, or GaInAsSb.

25

39. The semiconductor light emitter as claimed in claim 37, wherein said barrier layers are formed of GaAsSb, GaNAsSb, GaInNAsSb, GaNPAsSb, GaPAsSb, GaInNPAsSb, GaInPAsSb, or GaInAsSb.

5

40. The semiconductor light emitter as claimed in claim 35, wherein said barrier layers including antimony have a tensile strain relative to said GaAs substrate.

15

41. The semiconductor light emitter as claimed in claim 37, wherein said barrier layers including antimony have a tensile strain relative to said GaAs substrate.

20

25

42. A semiconductor light emitter,

comprising:

a GaAs substrate;

a quantum well active layer which includes
nitrogen and at least one other Group-V element, and
5 has a compressive strain relative to said GaAs
substrate;

barrier layers which are provided around
said quantum well active layer; and

an intermediate layer which is provided
10 between said quantum well active layer and said
barrier layers, and is formed of a Group-III-V
mixed-crystal semiconductor that includes antimony.

15

43. The semiconductor light emitter as
claimed in claim 42, wherein said intermediate layer
is formed of GaAsSb, GaNAsSb, GaInNAsSb, GaNPAsSb,
20 GaPAsSb, GaInNPAsSb, GaInPAsSb, or GaInAsSb.

25

44. The semiconductor light emitter as

claimed in claim 42, wherein said barrier layers have a tensile strain relative to said GaAs substrate, and said intermediate layer including antimony has a lattice constant that is larger than
5 that of said barrier layers and smaller than that of said quantum well active layer.

10

45. A semiconductor light emitter, comprising a quantum well active layer which includes nitrogen and at least one other Group-V element, wherein said quantum well active layer is
15 comprised of first layers and second layers stacked one over the other in cyclic arrangement, said first layers including In, Sb, and at least one other Group-V element, and said second layers including no or some In composition smaller than that of the
20 first layers, N, and at least one other Group-V element.

25

46. The semiconductor light emitter as claimed in claim 45, wherein said first layers are GaInAsSb, and said second layers are GaNAs.

5

47. A method of producing the semiconductor light emitter as claimed in claim 35, wherein at least the active layer is formed through crystal growth by an MOCVD method.

15

48. The semiconductor light emitter as claimed in claim 35, wherein said semiconductor light emitter is a surface emitting semiconductor layer.

20

49. An optical transmission module, comprising the semiconductor light emitter of claim

25

48 serving as a light source.

5

50. An optical transceiver module,
comprising the semiconductor light emitter of claim
48 serving as a light source.

10

51. An optical communication system,
comprising the semiconductor light emitter of claim
15 48 serving as a light source.

20

52. A method of producing the
semiconductor light emitter as claimed in claim 37,
wherein at least the active layer is formed through
crystal growth by an MOCVD method.

25

53. The semiconductor light emitter as
claimed in claim 37, wherein said semiconductor
5 light emitter is a surface emitting semiconductor
layer.

10

54. An optical transmission module,
comprising the semiconductor light emitter of claim
53 serving as a light source.

15

55. An optical transceiver module,
comprising the semiconductor light emitter of claim
20 53 serving as a light source.

25

56. An optical communication system,

comprising the semiconductor light emitter of claim
53 serving as a light source.

5

57. A method of producing the
semiconductor light emitter as claimed in claim 42,
wherein at least the active layer is formed through
10 crystal growth by an MOCVD method.

15 58. The semiconductor light emitter as
claimed in claim 42, wherein said semiconductor
light emitter is a surface emitting semiconductor
layer.

20

59. An optical transmission module,
comprising the semiconductor light emitter of claim
25 58 serving as a light source.

5 60. An optical transceiver module,
 comprising the semiconductor light emitter of claim
 58 serving as a light source.

10

 61. An optical communication system,
 comprising the semiconductor light emitter of claim
 58 serving as a light source.

15

 62. A semiconductor light emitter,
20 comprising:

 a GaAs substrate;

 a quantum well active layer which includes
 nitrogen and at least one other Group-V element, and
 has a compressive strain relative to said GaAs
25 substrate; and

barrier layers which are provided alongside said quantum well active layer, wherein said quantum well active layer and said barrier layers together constitute an active layer,

5 wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes both phosphorous and antimony.

10

63. The semiconductor light emitter as claimed in claim 62, wherein said barrier layers further include nitrogen.

15

64. The semiconductor light emitter as
20 claimed in claim 62, wherein said barrier layers are GaNPAsSb, GaPAsSb, GaInNPAsSb, or GaInPAsSb.

25

65. A semiconductor light emitter,
comprising:

a GaAs substrate;

a quantum well active layer which includes
5 Ga, As, and Sb, and has a compressive strain
relative to said GaAs substrate; and

barrier layers which are provided
alongside said quantum well active layer, wherein
said quantum well active layer and said barrier
10 layers together constitute an active layer,

wherein said barrier layers are formed of
a Group-III-V mixed-crystal semiconductor that
includes both phosphorous and antimony.

15

66. The semiconductor light emitter as
claimed in claim 65, wherein said barrier layers are
20 GaPAsSb, AlGaPAsSb, GaInPAsSb, or AlGaInPAsSb.

25

67. The semiconductor light emitter as

claimed in claim 62, wherein said quantum well active layer is a multiple quantum well active layer.

5

68. The semiconductor light emitter as claimed in claim 65, wherein said quantum well active layer is a multiple quantum well active layer.

10

69. The semiconductor light emitter as claimed in claim 62, wherein said semiconductor light emitter is a surface emitting semiconductor laser.

20

70. The semiconductor light emitter as claimed in claim 65, wherein said semiconductor light emitter is a surface emitting semiconductor laser.

25

5 71. An optical transmission module,
 comprising the semiconductor light emitter of claim
 69 serving as a light source.

10

 72. An optical transmission module,
 comprising the semiconductor light emitter of claim
 70 serving as a light source.

15

 73. An optical transceiver module,
20 comprising the semiconductor light emitter of claim
 69 serving as a light source.

25

74. An optical transceiver module,
comprising the semiconductor light emitter of claim
70 serving as a light source.

5

75. An optical communication system,
comprising the semiconductor light emitter of claim
10 69 serving as a light source.

15 76. An optical communication system,
comprising the semiconductor light emitter of claim
70 serving as a light source.

20

77. A semiconductor laser, comprising:
well layers; and
barrier layers, wherein said well layers
25 and said barrier layers are stacked one over the

other to form an active layer having a multiple quantum well structure, said barrier layers being made of a mixed-crystal semiconductor including nitrogen and at least one other Group-V element, said barrier layers including p-type impurity doped at concentration ranging from $1 \times 10^{17} \text{ cm}^{-3}$ to $1 \times 10^{19} \text{ cm}^{-3}$.

10

78. The semiconductor laser as claimed in claim 77, wherein the p-type impurity is carbon.

15

79. The semiconductor laser as claimed in claim 77, wherein a doping concentration of the p-type impurity in one of said barrier layers is lower in a region adjoining one of said well layers than in a region separated from said well layers.

25

80. The semiconductor laser as claimed in claim 77, wherein said well layers and said barrier layers have opposite strains.

5

81. The semiconductor laser as claimed in claim 77, wherein said well layers are made of a mixed-crystal semiconductor including nitrogen and at least one other Group-V element.

15

82. The semiconductor laser as claimed in claim 77, further comprising a resonator structure having a pair of multi-layered reflectors at opposite ends, said resonator structure including said active layer, and said semiconductor laser being a surface emitting semiconductor laser.

25

83. A method of making the semiconductor
laser of claim 77, comprising a step of doping
carbon in the barrier layers by use of an organic
5 nitrogen raw material.

10 84. An optical transmission module,
comprising the semiconductor laser of claim 77.

15 85. An optical transmission system,
comprising the optical transmission module of claim
84.

20